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DEVELOPMENT OF SLOWED DOWN BEAMS AT THE FRAGMENT SEPARATOR FOR FAIR*

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The feasibility studies of the slowed down beam setup involving deceleration of a ^{64}Ni beam at 250 MeV$/u$ to 13 MeV$/u$ in a thick Al degrader was performed at the FRagment Separator (FRS) at GSI. The experimentally measured energy spread and the nuclear reaction yields in the degrader are in good agreement with simulations.

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1. Introduction

The GSI/FAIR [1] facility will provide high-intensity beams of relativistic ions. Secondary beams of radioactive nuclei can be produced by in-flight projectile fragmentation or fission. With the beam currents planned for FAIR we expect radioactive beams at the final focal plane of the Super-FRS [2] with intensities sufficient for nuclear spectroscopy and reaction studies at energies around the Coulomb barrier. The low beam energy will be obtained

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by slowing down relativistic beam ions in a thick degrader. In contrast to the ISOL facilities, in experiments involving such slowed down beams, short lived fragments can be accessed with high survival rate after the deceleration. The high angular momentum transfer at Coulomb barrier energies opens a new field of high-spin investigations at the in-flight separation facilities. In the presented feasibility study, the characteristics of a primary ^{64}Ni beam after deceleration were investigated with a detector system optimized for an event-by-event identification at Coulomb barrier energies.

2. Simulations

Interactions of fragments penetrating through the matter govern the energy and angular straggling of the slowed down beams. The simulated values given by the MOCADI code [3] for a primary ^{64}Ni beam at 250 MeV/u, slowed down to 13 MeV/u in a homogeneous Al degrader of 3.95 g/cm^2 are shown in Fig. 1. A typical initial energy spread (σ_E/E) of 0.1% was assumed for the beam. The considerable energy and angular spread makes it necessary to track the ions after the degrader on an event-by-event basis. During the deceleration nuclear reactions also occur which lead to the production of unwanted isotopes. The simulated yields of the reaction products in the degrader are illustrated in Fig. 2 as a function of the beam energy. The integrated background contribution amounts to $\sim$ 1% of the slowed down ^{64}Ni ions in an energy window of $\pm$0.5 MeV/u at 13 MeV/u. This energy window corresponds to the time resolution of the TOF detectors used in the present experiment. All the parameters of the simulation take into account the detailed technicalities of the experimental setup discussed in next section.

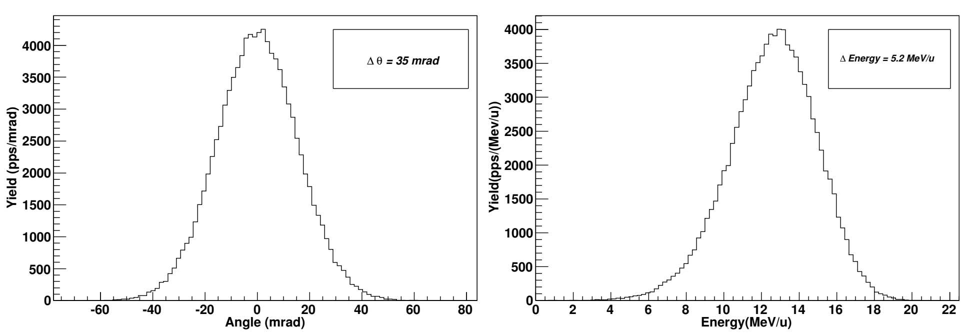

Fig. 1. Simulated angular spread (left) and energy straggling (right) of a ^{64}Ni beam after slowing down from 250 MeV/u to 13 MeV/u in a 3.95 g/cm^2 Al degrader.

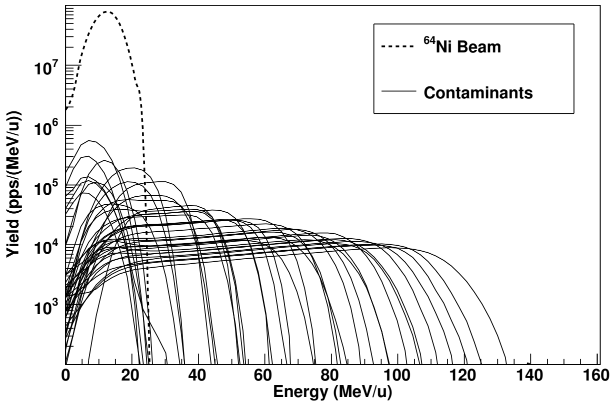

Fig. 2. The dominant curve (dashed) represents slowed down ^{64}Ni ions and the contaminants from nuclear reactions in Al degrader are shown in solid curves.

3. Experimental setup and results

In the present experiment a primary ^{64}Ni beam at 250 MeV/u was slowed down in a 3.95 g/cm^2 Al degrader at the FRS. The experimental setup is shown in Fig. 3 which consists of a plastic scintillator, a degrader, two position sensitive micro-channel plate (MCP) [4] detectors and a silicon (Si) detector. The Si detector was used for a rough estimate of the beam energy during the measurement. The proper beam velocity after the degrader was obtained from the Time-of-Flight (TOF) measurement between the fast scintillator and the MCP detectors. The extracted energy distribution (from TOF measurement) of the ^{64}Ni ions after the degrader is shown in Fig. 4. The width of the energy distribution is 8 MeV/u (FWHM). In order to estimate the background underneath the ^{64}Ni energy peak, the simulated background distribution (see Fig. 2) was scaled to the observed distribution

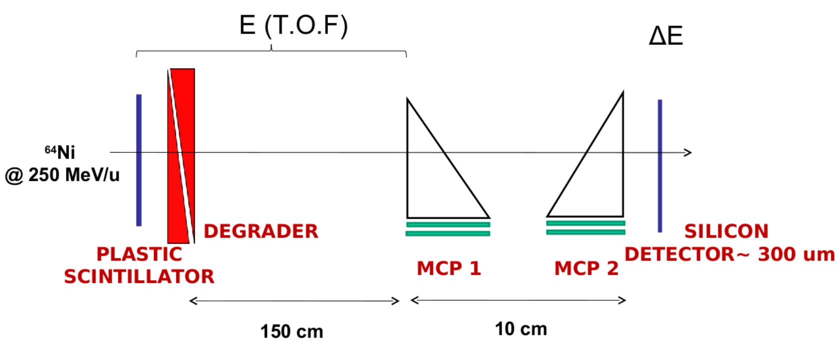

Fig. 3. Schematic setup for the slowed down beam experiment.

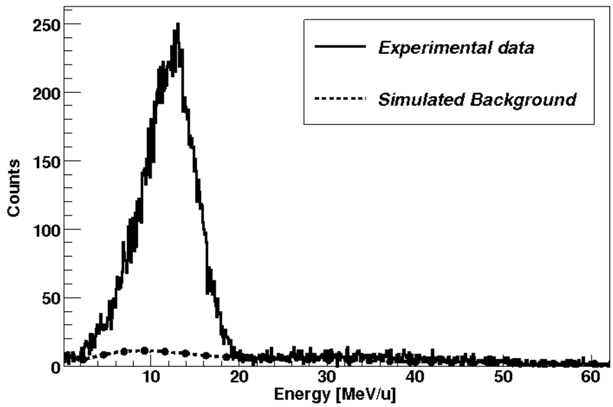

Fig. 4. Energy distribution of ^{64}Ni ions after slowing down in Al degrader. A final energy of 13 MeV/u was obtained with a width of 8 MeV/u. The dashed curve represents the simulated background.

in the range of 20–60 MeV/u. This resulted in a peak-to-background ratio of 2% in an energy range of 13 ± 0.5 MeV/u. The survival rate of the ^{64}Ni ions after passing through the degrader was 80% which agrees well with the simulations [5]. Unfortunately, the angular straggling could not be determined in the present experiment due to the limited size of the tracking detectors, positioned downstream from the degrader. In the final experimental setup the Si detector will be replaced by a $\Delta E - E$ telescope to identify the reaction products.

In conclusion, the presented experimental results are in good agreement with the performed simulations and hence, support the suitability of the slowed down beams for secondary reactions.

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